Name Date

HANDS-ON LAB

# Frame of Reference in Motion

When police officers investigate car accidents, they try to interview as many witnesses as possible. Observers watching the accident from nearby sidewalks and other cars (moving or still) will make different observations of each car's motion than the drivers and passengers do. The investigators must interpret each observer's description of the accident based on their frame of reference. The perception and description of motion depends on the location of the observer. For example, an observer that is moving alongside a car might describe the car's motion differently than an observer who is standing still and watching the same car pass by. **Figure 1** presents two views of the same car from two different frames of reference.

## MATERIALS

- safety goggles
- meterstick
- tape
- video recording device, such as a cellphone
- wind-up or remote-control car

In this activity, you will record the same event from various locations to determine how the frame of reference of the observer (the camera) changes the description of a moving object.

**RESEARCH QUESTION** How do different frames of reference change the description of a moving object?

## MAKE A CLAIM

How does the location of the camera affect the way motion is captured?

## SAFETY INFORMATION

- Wear safety goggles during the setup, hands-on, and takedown segments of the activity.
- Immediately pick up any items dropped on the floor so they do not become a slip/fall hazard.
- If recording the car from above, make sure to attach the camera securely to its support. It should not be placed above shoulder height, and one student in the group should be on-hand to catch the assembly should it begin to fall.
- Wash your hands with soap and water immediately after completing this activity.

**Figure 1:** Different perspectives of the same car

**a** Car filmed from the side

**b** Car filmed from behind

## PLAN THE INVESTIGATION

In your Evidence Notebook, write a procedure that you will follow to investigate how frames of reference change how you would describe the motion of the car. When developing your procedure, consider the following suggestions:

- Determine how you might use the meterstick and tape to make measurements or observations of the car's motion in each recording, as well as to design a course for the car to follow. For example, you might use tape to mark every 10 cm on the course and use the video camera's timer feature to estimate the time to cover each 10 cm distance.
- To compare the same event from different frames of reference, you will need to be able to recreate the car's motion exactly in repeated trials.
- In some trials, the camera will be stationary. Adjust the course and camera position so that the course fits in the frame of a stationary camera.
- Include in your plan the list of camera shots, including the position and motion of the camera in each shot, as well as the number of trials you will perform.

## COLLECT DATA

Carry out your procedure, and collect several recordings of how the toy car moves relative to the camera. Once you have made a recording, play it back and write down your observations and measurements. Design a table and use it to collect the same type of information for each camera location.

## CALCULATE

Calculate the estimated velocity of the car in each recording. Are the estimated velocities (speed and direction) you calculated the same regardless of frame of reference? Explain.

## ANALYZE

**1.** When the camera is still, what determines the perceived direction of the car's motion?

**2.** Suppose you record the motion of a car from the side. In one trial, the camera is moving at the same speed in the same direction as the car. In another trial, the camera is moving at the same speed in the opposite direction. If the car's speed is 0.3 m/s relative to its surroundings, what will its apparent speed relative to the camera be in each trial?

**3.** How does an observer's frame of reference affect how that observer perceives motion?

## CONSTRUCT AN EXPLANATION

**1.** When might a scientist or engineer need an understanding of reference frames to help answer a question or design a solution? Describe a specific example.

**2.** **Engaging in Argument from Evidence** From a distant point in space, the moon appears to orbit Earth in the same direction that Earth spins on its axis. If the moon stopped orbiting the Earth and remained still, would the moon's motion through the night sky seem to speed up or slow down to an observer standing still relative to Earth's surface? Use evidence from your investigation to answer.

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## DRAW CONCLUSIONS

Write a conclusion that addresses each of the points below.

**Claim** How does the location of the camera affect the way motion is captured? Explain whether your results support or refute your original predictions.

**Evidence** What evidence from your investigation supports your claim?

**Reasoning** Explain how the evidence you gave supports your claim. Describe in detail the connections between the evidence you cited and the argument you are making.

## EXTEND

Conduct another investigation using different car speeds, different camera angles or tilts, or curved courses. How do different frames of reference affect how you describe the motion of the car?